HARE – A NEW INTELLIGENT HAIL RECORDER FOR NETWORKS AND FIELD CAMPAIGNS

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I. INTRODUCTION

In this abstract the prototype of a new intelligent hail recorder (HARE) is described. An online device as well as an autonomous one are available for a large number of possible applications.

Nowadays hail typically is still measured with so-called hailpads. These are normally pieces of Styrofoam covered with a thin aluminum foil. After a hail event the hailpad has dints which can be evaluated. After evaluation the hailpad has to be replaced. There is no online information during hail storm, not even information on date and time of hail fall.

II. SENSOR DEVELOPMENT

An intelligent and simple hail sensor was developed, based on signal production with microphones, a quick signal analysis and recording possibility. For HARE small piezo-electric microphones inside a Macrolon body are used to detect hailstones. The prototype shown in fig. 1 has an octagonal shape, two microphones on top and bottom plate in the middle of the device, and a small electronic board. The reason for the octagonal shape was to avoid poor signals from hits just in the corners of a square.

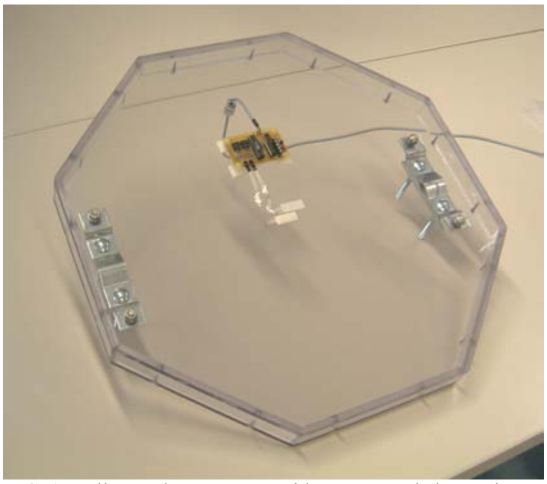

FIG. 1: Hail recorder prototype with sensors and electronics.

A hailstone hitting on the surface produces waves on the sensor body and a voltage in the piezo-electric microphones, see fig. 2. Obviously the top signal starts first and shows some disturbances at the beginning. Using top and bottom sensors makes the device more independent from the location of the hailstone hits (similar results in the middle or at the edge). The voltage depends on the strength of the hit. After A/D-conversion a micro-controller estimates the hailstone size in combining both sensor signals (top and bottom). Each hail event is stored in the internal memory together with date and time. The memory can be read out via serial port at any time after one ore more hail events.

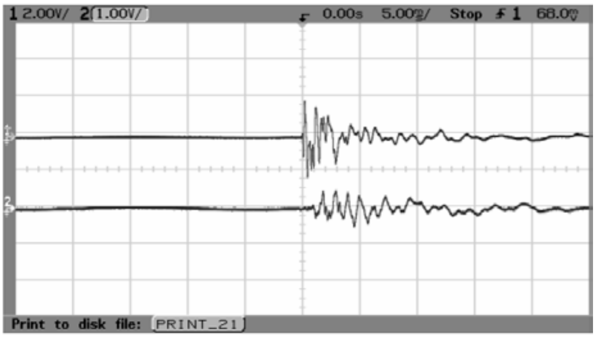

FIG 2: Sensor signals from top and bottom plate.

III. MEASUREMENTS AND CALIBRATION

From the signals shown in fig. 2 it was a large step to the final signal analysis. Main idea was to calculate mean signal values for defined time intervals. One example of those mean values is given in fig. 3. For a wood sphere of 15mm in diameter the decreasing amplitude is plotted as a function of time. The good damping of the housing material can be seen and after approx. 7ms the device would be ready for the next impact.

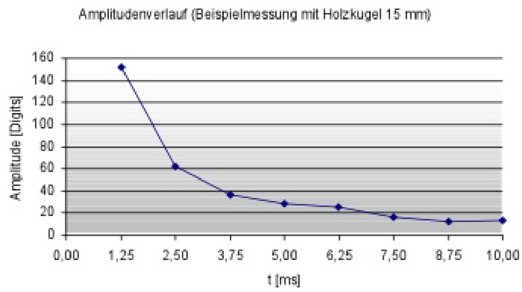

FIG. 3: Mean amplitude damping with time.

The hailstones are classified in four danger categories. Mean theoretical values of diameter, velocity, mass, momentum, and energy of these classes are given in tab. 1.

Diameter d [mm]	Velocity v [m/s]	Mass m [g]	Momentum p [kg·m/s]	Energy E_{kin} [J]
5	5	0,06	3,01E-04	7,53E-04
15	9	1,63	1,46E-02	6,58E-02
25	12	7,53	9,03E-02	5,42E-01
35	14	20,65	2,89E-01	2,02E+00

TABLE 1: Hailstone parameters (mean values).

To relate the measurements to the danger of damage it is necessary to calibrate the sensor. For this purpose a hail gun was built. There is a European testing standard for solar panels the gives the rules. Ice spheres with a diameter of 25mm and a velocity of 22m/s have to be shot on the panels.

FIG. 4: Pneumatic hail gun with HARE below.

In the top of fig. 4 the gun can be seen and there is a hail recorder below the frame constructed with Bosch profiles. Just above the HARE two laser light sheets are mounted for velocity detection of ice balls. They were specially produced according to the above mentioned standard. Some examples of water and orange juice ice balls are shown in fig. 5. Different materials were used to simulate hail with various densities and textures.

FIG. 5: Example of ice balls from water and orange juice.

More than 100 shots with velocities from 10m/s up to 30m/s were conducted with different ice balls. The overall calibration data are shown in fig. 6. The HARE signal given in internal digits is presented as a function of ice ball momentum. The momentum was calculated by the measured velocity and the weight of each single ice ball taken before the shot. The results of different materials are sorted by symbols and colors. In addition, six measurements of a free falling mouse ball are included. They are connected by a line and show the elastic border. Nearly all ice balls smash on the HARE surface, their signals are smaller than the mouse ball signals. Also obvious are the smaller signals of orange juice balls, resulting from a lower density and a softer texture.

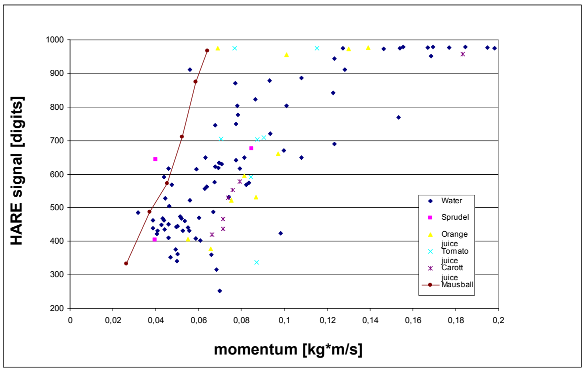

FIG. 6: Calibration results for different ice balls.

The experiments were controlled by a LabView software. With this software the user set the pressure of the hail gun, e.g. the velocity of the ice balls, started the light sheets, and finally, shot. As output the signal was shown on the screen, the velocity was evaluated and the data of each shot were stored in an excel file.

IV. APPLICATIONS

First application idea was to use the online HARE at Spanish solar power plants to prevent the expensive modules from damage, see fig. 7. The serial port will be replaced by some bus communication, e.g. SDI-12 bus. The hail sensors around the solar plant are directly connected to the control room and deliver a warning when a hailstorm is coming. Then the drives of the solar modules bring them into the most save position. First tests of this application will be conducted during spring and summer 2010.

FIG. 7: HARE, solar power plant, and author.

Latest application for the autonomous HARE will be a small network of at least ten stand-alone devices within a hailstorm project in the Black Forest around Villingen-Schwenningen. Hopefully, in 2010 the first real hail data will be produced from this campaign.

V. REFERENCES

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[2] Löffler-Mang M., Blahak U.: Estimation of Radar Reflectivity from Measured Snow Spectra. *J. Appl. Meteorol.* **40** (2001), 843-849.